Wideband Space Network Emulator to Enable Mission Concept Simulations and Human-Robotic Exploration

Space Internet Workshop III

June 4-6, 2003

Michael A. Cauley, NASA GRC

(216) 433-3483

Michael.A.Cauley@nasa.gov

Wideband Space Network Emulator
INTRODUCTION

INTRODUCTION

- NREN has developed a Wideband Space Network Emulator for conducting realistic planetary mission scenarios in support of other interdisciplinary teams.
- Includes programmable interplanetary delay. We have emulated the complete communications link from the Exploration Site back into Mission Control at JSC.
- Interdisciplinary teams (space suit, robotics, etc.) are working together very early in the EVA mission concept phase to best integrate individual products.
- Proposed mission scenarios and prototype hardware are tested in “relevant environments” on Earth. These environments are chosen to closely approximate different aspects of candidate planetary destinations.
- All teams participate in the early development and definition of communications performance requirements. This creates ‘*compatibility*’ early in the design.

NREN - NASA’s Research and Education Network... is part of NASA’s CICT program.

Wideband Space Network Emulator

WIDEBAND SPACE NETWORK EMULATOR - WHAT IS IT?

Key Components of the Wideband Space Network Emulator include:

- STING - Satellite Trailer for Internet Next Generation / TELSA - Transatlantic Earth Station Laboratory
- P-ONE - Planetary Ohio Network Emulator
- LPSM-2 - Lunar / Planetary Science Module -2
- Other Technologies
  - Surface Proximity Network (802.11b + microwave)
  - Proximity Voice Communications
    - EVA Suit array microphones with DSP noise cancellation
    - Between field team (TDMA voice comm system)
  - VoIP
    - Support EVA comms back to Base Camp
    - Provide POTS service to researchers at Field Site (cell/PCS is typically not available)
  - MPEG-2 Streaming Video over IP
  - PCMon - Network Performance Monitor

Wideband Space Network Emulator
STING - Satellite Terminal for Internet Next Generation

NREN's "Satellite Terminal for Internet Next Generation" (STING) is a transportable earth station designed to support high-speed networking research from geographically remote locations. The completely self-sufficient STING is linked via commercial Ku-band satellites to a large gateway earth station located at NASA GRC. This gateway is co-located with the NREN network and other NASA networks.

When deployed, the tow vehicle serves as a Mobile Network Operations Center (MNOC) linked to the trailer via high-speed microwave link. The STING is completely self contained (power, HVAC, etc.) and untethered. The MNOC may be located up to five miles from the STING.

The STING can operate full-duplex from 9.6-Kbps to 45-Mbps, and is licensed for use over all domestic/ international Ku-band satellites shown on the FCC Permitted Space Station List.

One person quick set-up / tear-down. (Operational within 1 hour)

Wideband Space Network Emulator
p-ONE - Planetary Network Delay Emulation System

The "Planetary - Oho Network Emulator" (p-ONE) inserts a programmable delay into the satellite network.

Wideband delay capability, up to 10 Mbps. Long temporal delay capability, designed for at least 20 minutes of wideband delay.

Packet losses very low (no observed packet losses observed during testing), negligible data skew (nanoseconds).

Capable of delaying all network traffic passing through the system, or p-ONE can be programmed to selectively delay only specific address traffic.

Hardware: Dual Pentium-III (S/370), 4RU, 512 MB DIMM, 41GB drive, dual Ethernet

Software: Linux operating system with p-ONE software.

Wideband Space Network Emulator
LPSM2 - Lunar Planetary Science Module 2

The LPSM1 was designed as a "mobile field work bench" for suited astronauts.

The LPSM2 is designed for autonomous and remotely controlled data collection, the LPSM2 includes the following science instruments:

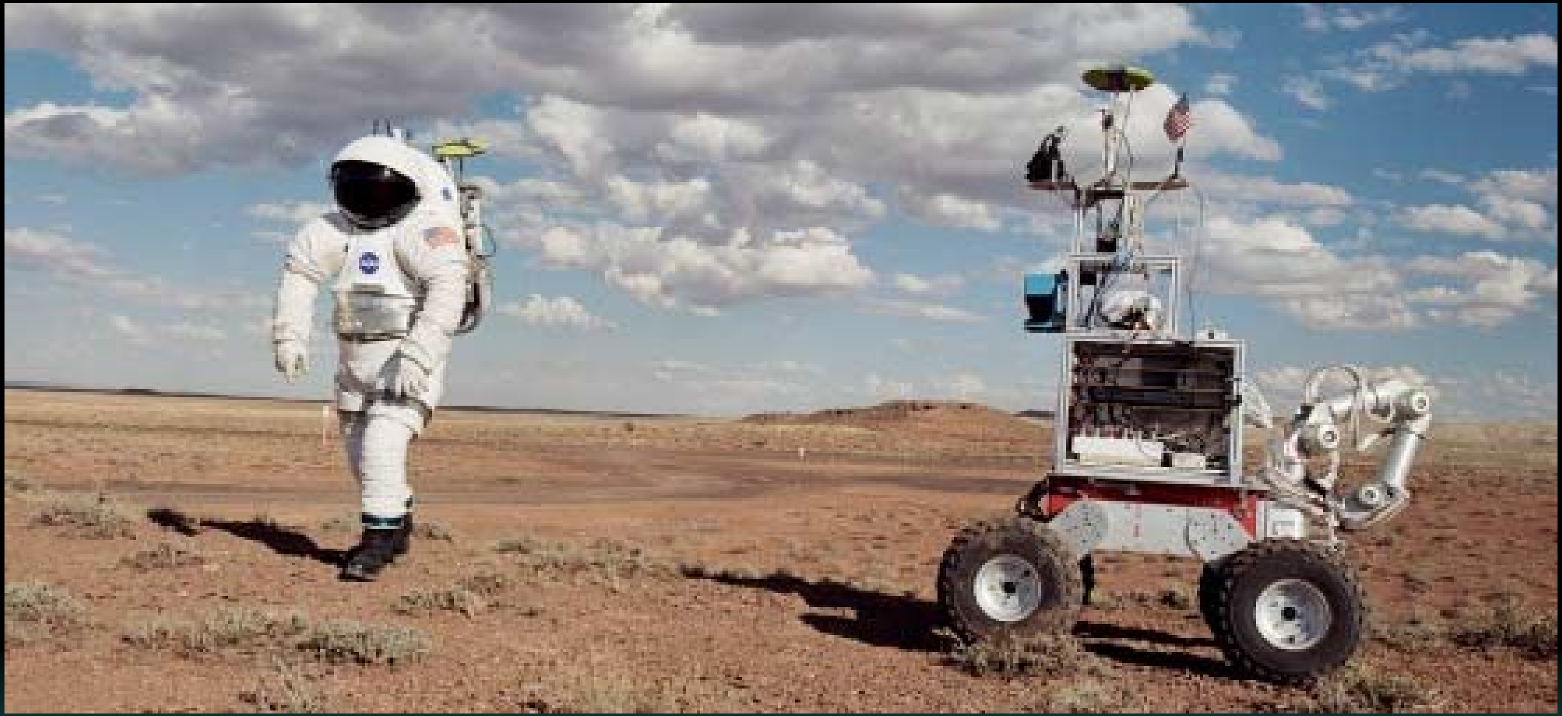
- Spectroradiometer - 3 band, 0.4 – 2.5 micrometer
- Infrared Pyrometer - 8.5 – 14 micrometer
- Web Cam
- Magnetometer
- GPS Receiver
- Geiger Counter (Homeland Security applications)

LPSM2 developed by Dr. Richard Beck, University of Cincinnati

LPSM2 during preparations for June 2003 Ground Truthing Exercise

Wideband Space Network Emulator
Sept 2002 - Human Robotic Exploration

Goal: Advance communication technologies necessary for combined human-robotic exploration of space



NASA's Human Robotic Interaction - HRI concept for exploration includes humans and robots working closely together in a complimentary manner to accomplish mission goals.

Humans assure the overall "***quality***" and enable dramatically increased mission "***autonomy***". Robots provide a level of measurement "***accuracy***" unobtainable by a suited human.

Image taken from September 2002 HRI experiments near Meteor Crater, Arizona

Wideband Space Network Emulator
Sept 2002 - Human Robotic Exploration

Fig 1 - Human Robotic Interaction

Fig 2 - ERA Robot with JSC Fuel Cell

Fig 3 - Suit with “Info Pack”

Fig 4 - LPSM1 with GeoPhones (dry run)

Fig 5 - LPSM1 with Suit Subject (dry run)

ERA = Exploration Robotic Assistant

Wideband Space Network Emulator
Sept 2002 - Human Robotic Exploration

Video Clip: Suit subject deploying GeoPhones (51 sec)

Wideband Space Network Emulator
Sept 2002 - Human Robotic Exploration

Video Clip: ERA ‘robot’ powered by Fuel Cell (1:25 sec)

Wideband Space Network Emulator
Sept 2002 - Human Robotic Exploration

FIELD EXERCISE ACCOMPLISHMENTS

- Extended proximity communications (voice, video, and data) via satellite back to the Exploration Planning and Operations Center (ExPOC) ‘mission control’ at JSC.
- Included realistic transit delays for voice and video to simulate a Mars mission delay. Developed a basic message exchange protocol for communicating over such distances.
- Integrated a TDMA based voice communication system dramatically improving voice comms between suit subject, ERA robot, and support team. Voice comm from suit subject and robot given “priority” over other team member belt packs (safety).
- Incorporated live and delayed streaming MPEG-2 video and audio from the Field Site back to the ExPOC located in “Mission Control” at JSC.
- Upgraded EVA video system to include multiple video streams.
- Cleaned up space suit audio making speech recognition more reliable.

Wideband Space Network Emulator
April 2003 - Intelligent Systems "Mobile Agents"

GOAL: Test software "agents" developed to automate the CapCom role during EVA activities.

Software agents running on several mobile platforms provide services such as crew health monitoring, position location, recording voice comments and pictures, initiating tasks via voice command.

Tested a voice-operated system that monitored crew health, tracked their locations and helped keep them on schedule-all while listening and recording their observations.

"Agents" provide automated support needed to keep EVA's on schedule with updated navigation and status information and assist the astronauts in performing tasks.

The Mars Society's - Mars Desert Research Station

Note: Field Exercise performed as "Crew Rotation 16" of the Mars Desert Research Station (MDRS)

Wideband Space Network Emulator
April 2003 - Intelligent Systems “Mobile Agents”

Aerial view of STING deployed at the Mars Desert Research Station (MDRS)

Wideband Space Network Emulator
April 2003 - Intelligent Systems “Mobile Agents”

STING deployed at The Mars Society, Mars Desert Research Station - MDRS in Southern Utah, April 2002.

The large structure in the background is the “hab” with a greenhouse in front. On top of the hill between the hab and STING is a telescope facility.

Wideband Space Network Emulator
April 2003 - Intelligent Systems “Mobile Agents”

Wideband Space Network Emulator
April 2003 - Intelligent Systems “Mobile Agents”

Wideband Space Network Emulator
April 2003 - Intelligent Systems "Mobile Agents"

Video Clip: Suit Subject taking a ride on second generation ERA robot. (15 sec)

Wideband Space Network Emulator
April 2003 - Intelligent Systems "Mobile Agents"

FIELD EXERCISE ACCOMPLISHMENTS

- Extended proximity communications (voice, video, and data) via satellite back to the ExPOC 'mission control' at JSC.
- Software agents automatically relayed EVA data (photographs, voice commentary, and alerts) back to JSC and the Northern California Mars Society support team.
- Provided network performance monitoring using PCMon.
- Added two independent Voice over IP (VoIP) services.
- Held a live two-way broadcast quality video teleconference between the test site and NASA Ames.

Wideband Space Network Emulator
June 2003 - Ground-Truthing Experiment

Science Objectives, Project Goals

- **Demonstrate** the benefits of using hybrid networking to extend mass-storage and grid computing capabilities to remote exploration teams -. *Application*: Remote exploration teams include both Earth and planetary explorers.
- **Empower exploration teams** to make decisions at a remote location using these resources, without leaving the site.
- **Demonstrate** the ability to ground-truth real-time EO-1/Hyperion imagery with actual measurements taken on the ground. *The ground-truthing process validates satellite imagery, improves the value of the imagery to explorers, and can also determine the causes of any "variability" detected in an image.*
- **Use the grid** to compute up to 64 band-ratios of the satellite imagery simultaneously. Provide the results to scientists at GRC and in the field for immediate visual analysis.
- **Use the ground-truthed results** to confirm the locations of similar geological compositions in the field

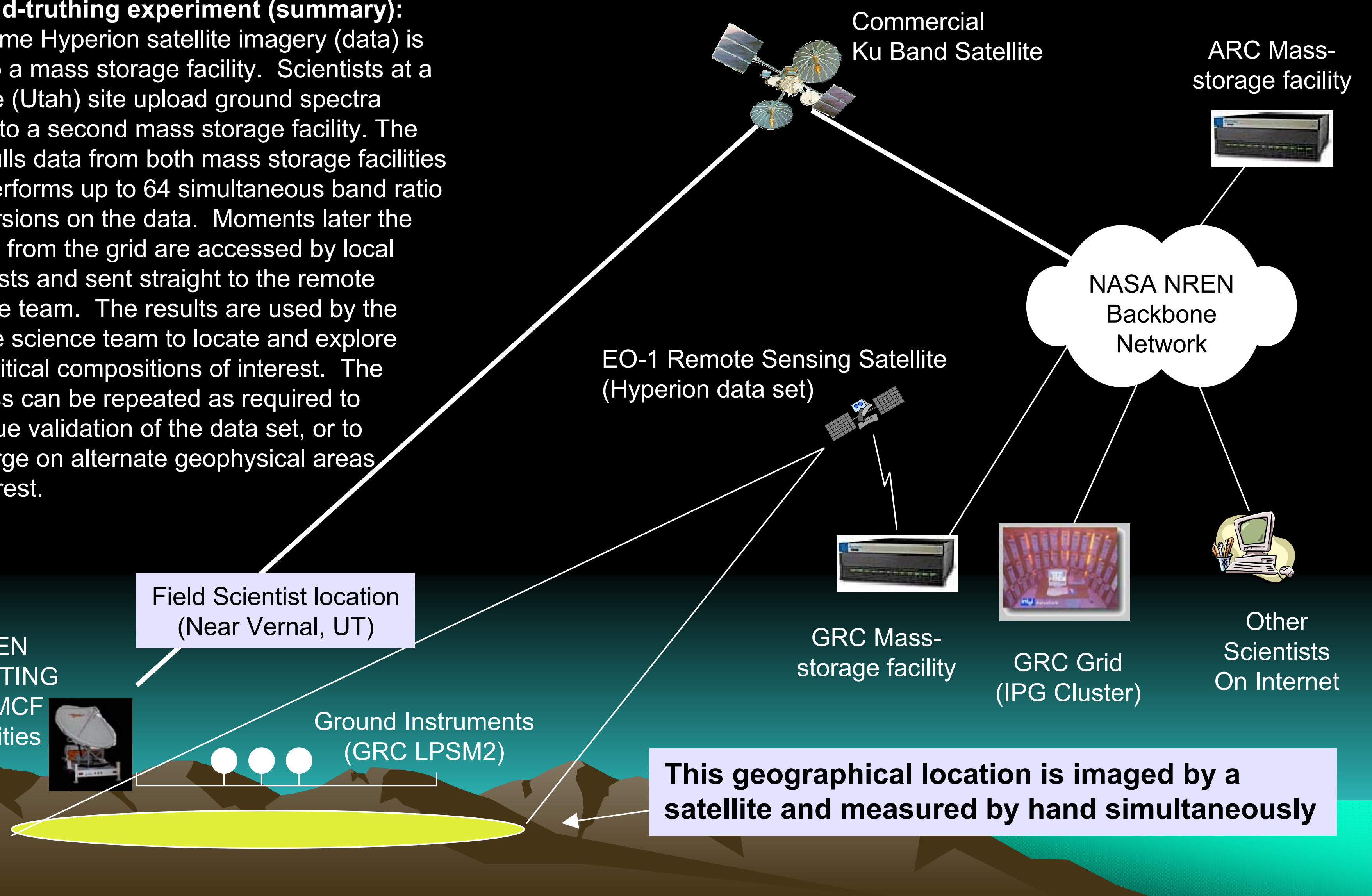
Complete CICT/CNIS Milestone 5.1.3 in June 2003

Wideband Space Network Emulator
June 2003 - Ground-Truthing Experiment

Satellite View of Ground Truthing Test Site near Vernal, UT

Wideband Space Network Emulator
June 2003 - Ground-Truthing Experiment
Experiment Resource Architecture

Ground-truthing experiment (summary):
Real-time Hyperion satellite imagery (data) is sent to a mass storage facility. Scientists at a remote (Utah) site upload ground spectra (data) to a second mass storage facility. The grid pulls data from both mass storage facilities and performs up to 64 simultaneous band ratio conversions on the data. Moments later the results from the grid are accessed by local scientists and sent straight to the remote science team. The results are used by the remote science team to locate and explore new critical compositions of interest. The process can be repeated as required to continue validation of the data set, or to converge on alternate geophysical areas of interest.



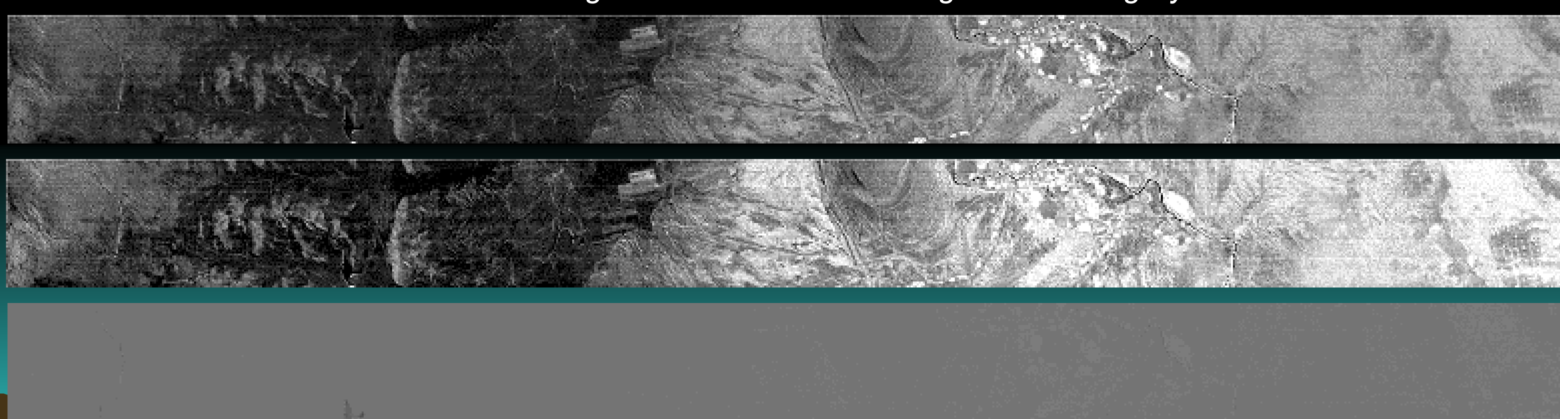
Wideband Space Network Emulator
June 2003 - Ground-Truthing Experiment

Software testing - Preliminary IPG software output

The GRC team posted some sample images on the web for preliminary Field Scientist review on April 30. The sample band-ratio images below were produced from a real, archived EO-1 satellite/Hyperion Instrument data file (HDF - the same file format the IPG is receiving the week of June 23 from USGS).

Up to 64 band ratios will be simultaneously analyzed by the IPG using the real-time EO-1 image file while the team is in the field.

Description: For the hyperspectral band ratio 43/83 below, the top image is the conversion of the ratio to 10 discrete grayscale levels, the middle is the conversion of the ratios between 1-99% to grayscale, and the bottom image is the conversion of log of ratios to grayscale.



Wideband Space Network Emulator
Sept 2003 - Human Robotic Exploration

PRELIMINARY

This years field exercise will advance earlier work, further developing realistic EVA scenarios. This field exercise will likely include:

- A 1G "Lunar Rover Vehicle" (LRV) provided by the USGS. This rover was constructed in the 1960's as a Lunar Rover Trainer for training suited Apollo astronauts for moon missions.
- Testing of The Mark III "H" Space Suit, and possibly the ILC "I" Space Suit.
- Much longer EVA distances (up to 2000' ft) with 25% of time on rover, 75% off.
- Inclusion of a JSC developed experimental Fuel Cell to power the 1G Lunar Rover

Our goals are to:

- Integrate communications into USGS 1G Lunar Rover.
- Development of voice and data 'Comm Relay' to cover extended range.
- Complete integration of a noise canceling 4-microphone array mic into the suits.
- Provide satellite connectivity, VoIP services, audio/video streaming, network performance monitoring.

Where?

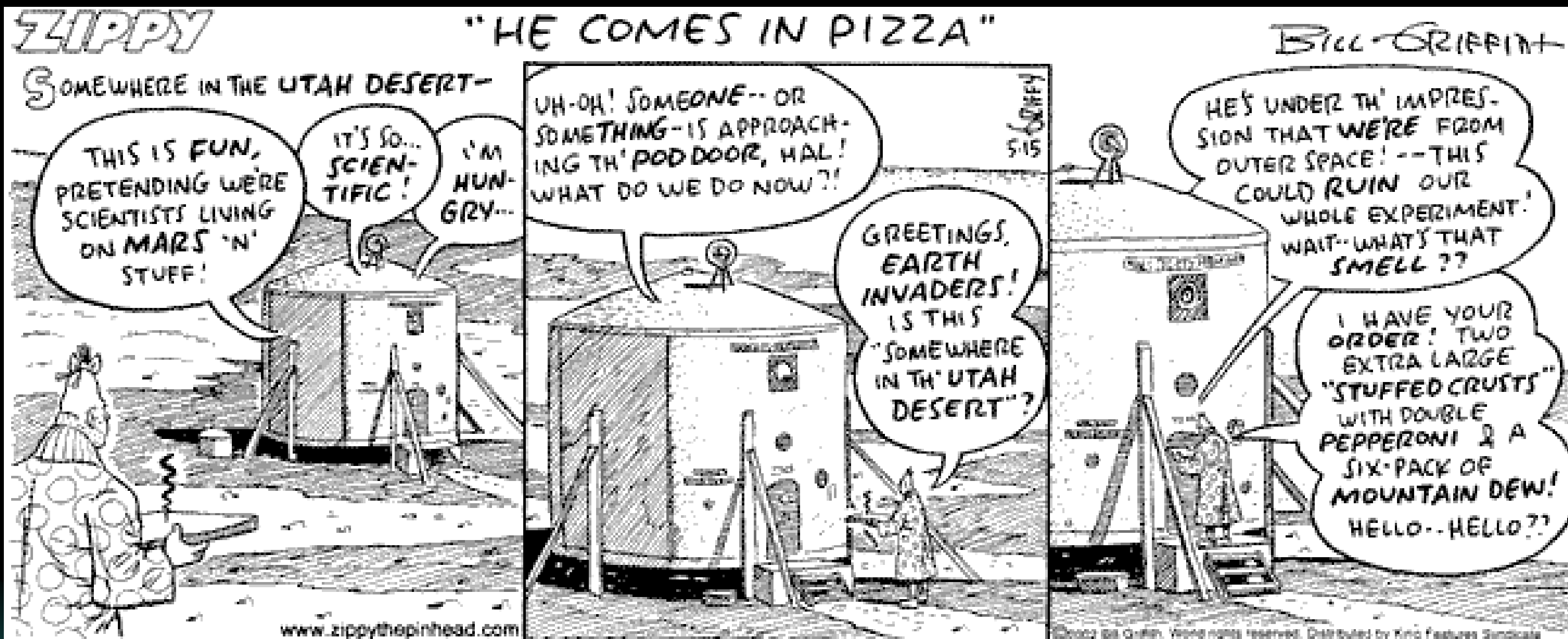
- A remote desert location in northern Arizona

NOTE: Although planning is in progress, funding has not been secured to confirm our participation

Wideband Space Network Emulator
SUMMARY

- NREN has developed a Wideband Space Network Emulator for conducting realistic planetary mission scenarios in support of other interdisciplinary teams.
- Includes programmable interplanetary delay. We have emulated the complete communications link from the Exploration Site back into Mission Control at JSC.
- Interdisciplinary teams (space suit, robotics, etc.) are working together very early in the EVA mission concept phase to best integrate individual products.
- Proposed mission scenarios and prototype hardware are tested in “relevant environments” on Earth. These environments are chosen to closely approximate different aspects of candidate planetary destinations.
- All teams participate in the early development and definition of communications performance requirements. This creates ‘*compatibility*’ early in the design.

Figure is a true color image of Ames Research Center taken by the EO-1 “Hyperion” instrument.



Courtesy: King Features Syndicate
http://www.zippythepinhead.com